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Investigation of a cyclogenesis event, 26–29 July 1988, using satellite imagery and numerical model diagnostics

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Summary

This paper examines a cyclogenesis event which was accompanied by heavy rainfall over North Wales and northern England. Satellite imagery revealed a distinct double structure to the cloud pattern prior to cyclogenesis, each cloud element corresponding to a well-defined frontal zone and rain band. The regions of cloud and precipitation were related to distinct ascending warm conveyor belts, the configuration of which bore a marked similarity to some other cases of cyclogenesis. The fine-mesh numerical-model forecast based on data at 06 GMT on 28 July 1988 gave a far superior forecast of rainfall to that based on data received 6 hours earlier. Differences between the two model runs could be attributed to aircraft reports which were available for the 06 GMT model run. Furthermore, clues in the imagery which could have helped the forecaster to improve upon the available numerical-model guidance are presented.

1. Introduction

On 28 July 1988 a deepening depression crossed the British Isles from the south-west giving very heavy rainfall in a band extending from Ireland, across the Irish Sea and North Wales, and into northern England (Fig. 1(a)). In the 12-hour period to 21 GMT on 28 July rainfall totals exceeded 20 mm over much of this area, with 49 mm recorded on Anglesey. By contrast, much of central and south-east Britain remained dry. Fig. 1(b) shows forecast rainfall totals for the period 06–18 GMT on 28 July derived from the fine-mesh model, data time 00 GMT on 28 July. Considerable totals were forecast for southern Britain which remained mostly dry, whereas over northern England, rainfall amounts were underforecast.

This paper examines reasons for the distinctive rainfall distribution, looking in particular for clues in the satellite imagery which could have alerted the forecaster to the poor numerical-model guidance. A simple airflow model is presented relating the cloud patterns to the weather distribution, and comparisons are made with other cases of cyclogenesis. Reasons for the poor guidance from the model's midnight run are also investigated.

2. Broad-scale evolution

The broad-scale evolution from 26 to 29 July 1988 as demonstrated in the imagery, the upper air and at the surface is shown in Figs 2 to 4. Late on 26 July two adjacent cloud structures (labelled F1 and F2 in Fig. 2(a)) accompanied the developing depression which lay within a strong baroclinic zone forward of a confluent upper trough (Fig. 3(a)). The double structure persisted as the system moved eastwards with the upper trough (Figs 2(b) and 3(b)).

A narrow band of cloud (with embedded convection), which extended south-west from F1, marked the

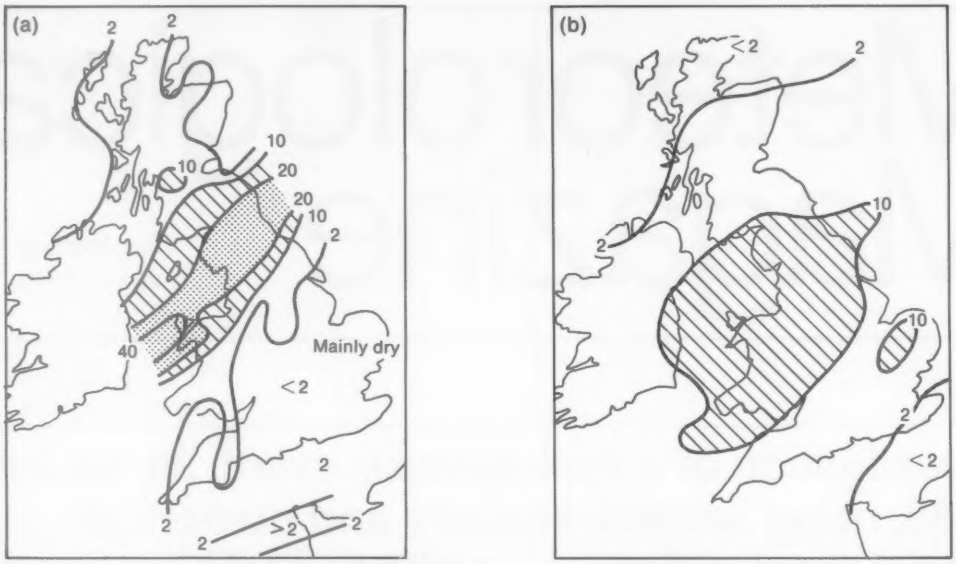

Figure 1. (a) Total rainfall (mm) during the period 09–21 GMT on 28 July 1988 (information derived from the London Weather Centre Daily Summary) and (b) total grid-point accumulations of rainfall (mm) forecast by the fine-mesh model for the period 06–18 GMT on 28 July 1988 using data for 00 GMT on 28 July. Hatching denotes accumulations greater than 10 mm and stippling denotes accumulations greater than 20 mm.

historical cold front (which will be referred to as the 'inner' or 'southern' front). The centre of the surface low lay further north, beneath an area of warm cloud-tops, between F1 and F2. Surface observations (Figs 4(a) and 4(b)) suggested that the surface low was part of a separate northern frontal zone corresponding to cloud mass F2, although this front was difficult to locate using the imagery alone. The relationship between F1, F2 and the surface features was preserved as the system crossed the British Isles during 28 July (Figs 2(d) and 2(e), and Fig 4(b). A movie-loop of Meteosat images highlighted plumes of thin cirrus (for example at 45° N, 25° W in Fig. 2(c)) moving rapidly east-north-east across the system. These delineated the jet-stream axis which lay between F1 and F2, indicated by UU on Fig. 2(d).

During 28 July, cloud area F2 expanded as it crossed northern Britain ahead of the sharpening upper trough, and contained much embedded convection. As the associated surface low deepened and developed a vigorous circulation over the North Sea early on 29 July (Fig. 4(c)), cloud area F2 began to rotate, forming a hook around the deepening low (Fig. 2(f)). Developing bands of deep convection extended southwards from the depression centre towards F1 through the area previously free of upper cloud. However, F1 and F2 were moving further apart in the increasingly diffluent flow ahead of the upper trough, so the two systems never merged completely.

The two separate well defined cloud-bands had important repercussions on the rainfall distribution (Fig. 5). The large area of heavy rain which moved from Ireland to northern England during the day was related to cloud mass F2. Along the north coast of France, a persistent band of heavy rain occurred beneath the narrow band of warmer cloud-tops FF in Fig. 2(d), which corresponded to the inner front. Maintenance of this overall pattern led to the rainfall distribution depicted in Fig. 1(a).

3. Three-dimensional structure

The rainfall distribution can be explained using the simple conceptual model shown in Fig. 6. The configuration of the conveyor belts shown in Fig. 6 was probably maintained throughout the life cycle of the system. This configuration is remarkably similar to that which accompanies 'instant occlusion' events (e.g. McGinnigle *et al.* 1988, Young 1988) Two main ascending warm conveyor belts (WCBs) were identified:

(a) W1, which was a gently ascending rearward-sloping flow giving rise to the broad cloud band extending from south-west to north-east across southern England and northern France. At its southern limit was the inner front marked by the rain band over the north coast of France. The northern limit of W1 was delineated by the band of cirrus, UU (Fig. 2(d)), marking the jet axis. Although UU appears separate from FF in Fig. 2(d), these two cloud bands will be shown to be part of the same frontal zone.

(b) W2, which emerged from beneath W1 and ascended rapidly over the intensifying northern frontal zone, producing the separate cloud canopy F2. This ascent, coupled with release of potential instability within W2 (shown by the lumpy cloud structure over south-east Ireland (Fig. 2(d)) led to widespread heavy rain as shown in Fig. 5.

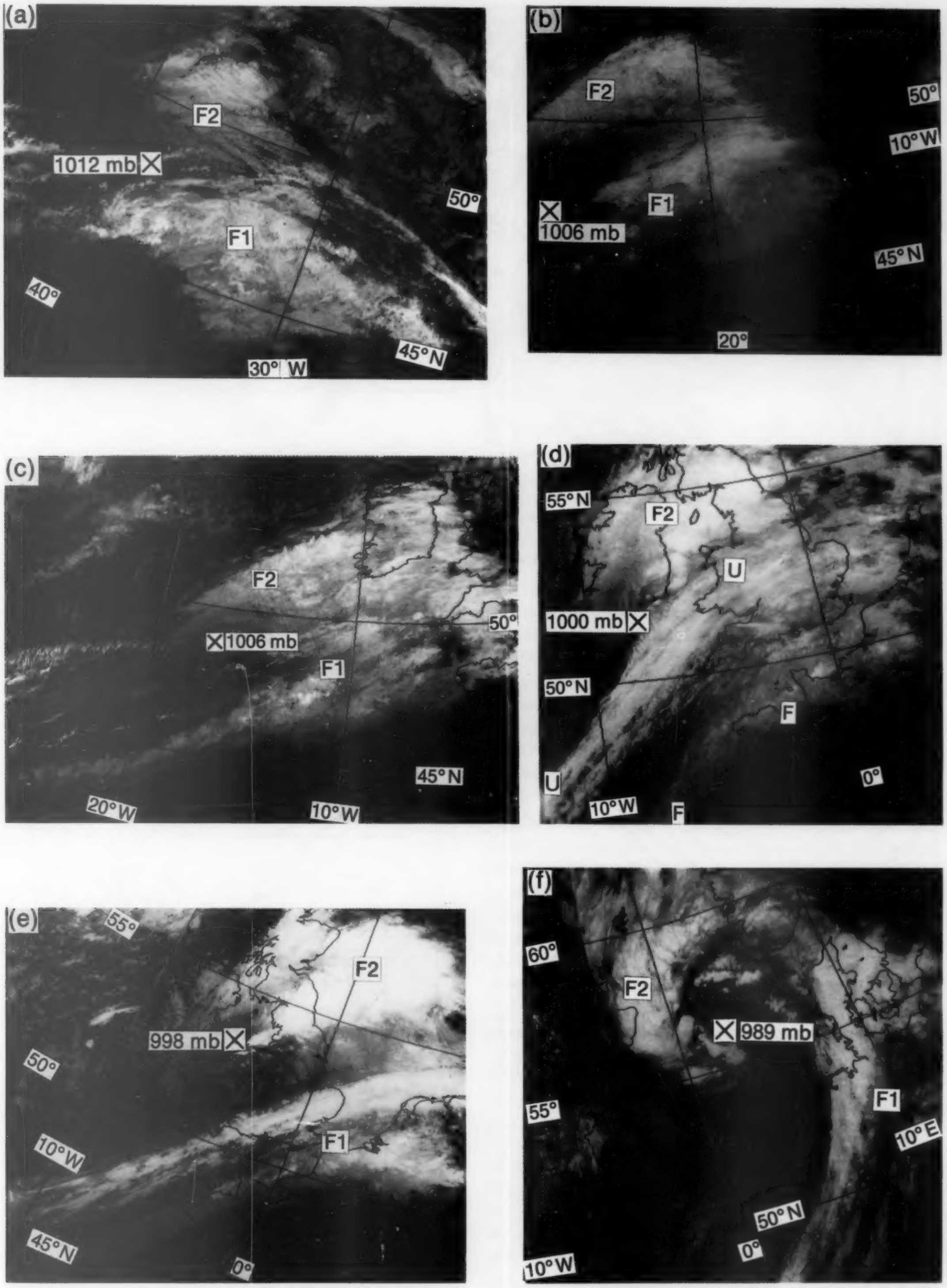

Figure 2. NOAA infra-red satellite imagery for (a) 1657 GMT on 26 July, (b) 0510 GMT on 27 July, (c) 1646 GMT on 27 July, (d) 0759 GMT on 28 July, (e) 1453 GMT on 28 July and (f) 0503 GMT on 29 July 1988. F1, F2, F and U are referred to in the text. The depression centre is shown by a cross with estimated central pressure alongside. Photographs by courtesy of University of Dundee.

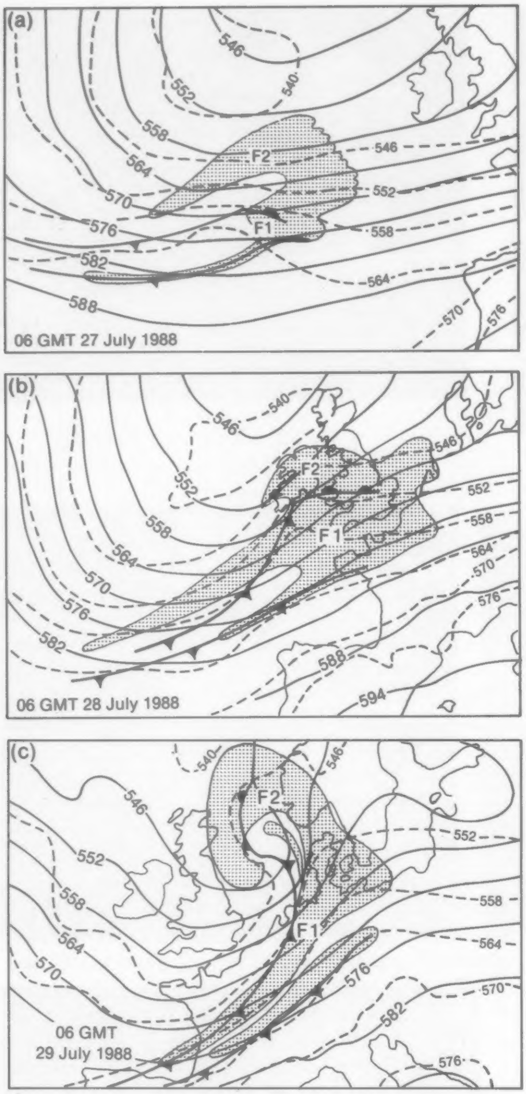

Figure 3. Upper-air analyses (derived from the fine-mesh model), major middle- and upper-cloud areas (stippled) and fronts at 0600 GMT on (a) 27 July, (b) 28 July and (c) 29 July 1988. Continuous lines are 500 mb heights, and dashed lines are 1000–500 mb thickness (both dam). F1 and F2 are referred to in the text. A small phase error between the observed frontal and cloud positions and the model's thermal ridge is present in (a).

W1 and W2 could be identified on the radiosonde soundings presented in Fig. 7. At 00 GMT on 28 July the base of W1 was the marked inversion which lay at 700 mb at Camborne (Fig. 7(a)), rising to 580 mb at Crawley (Fig. 7(b)). W2 was evident below 800 mb on the 12 GMT Camborne sounding (Fig. 7(c)). It was characterized by the moist, stable layer exhibiting well backed flow and a low-level jet of 205° 50 kn at 939 mb. Above 450 mb the sounding penetrated the northern limit of W1.

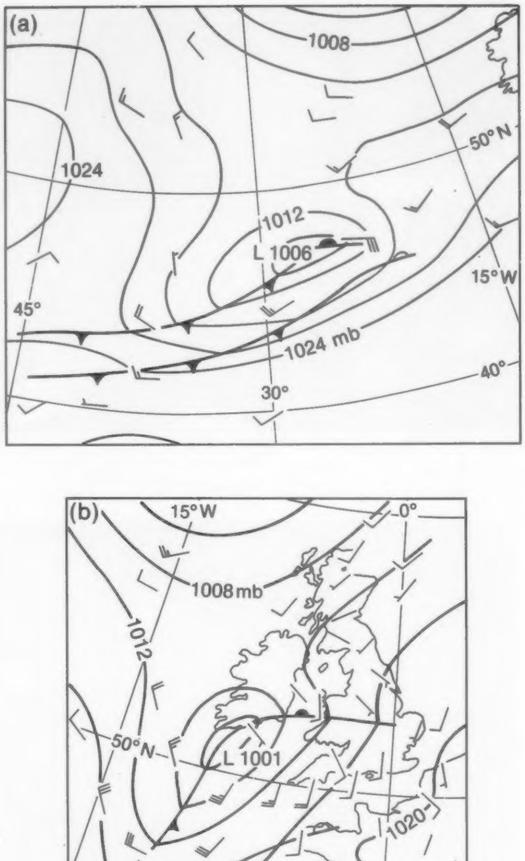

Figure 4. Surface analyses and wind observations for (a) 0600 GMT on 27 July, (b) 0600 GMT on 28 July and (c) 0600 GMT on 29 July 1988. Upper and surface frontal symbols are used where appropriate.

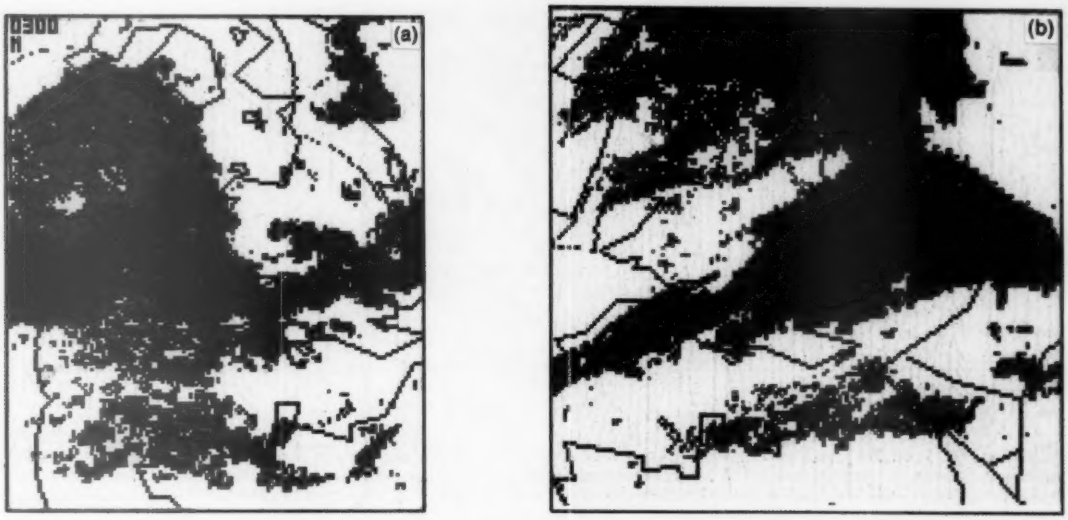

Figure 5. Combined satellite and radar imagery from the European COST-73 network for (a) 0300 GMT and (b) 1200 GMT on 28 July 1988. Blue represents cloud areas colder than $-15\ ^\circ C$. Rainfall rates are: pink $<1\ mm\ h^{-1}$, green $1\text{–}3\ mm\ h^{-1}$, yellow $3\text{–}10\ mm\ h^{-1}$, red $10\text{–}32\ mm\ h^{-1}$ and black $>32\ mm\ h^{-1}$.

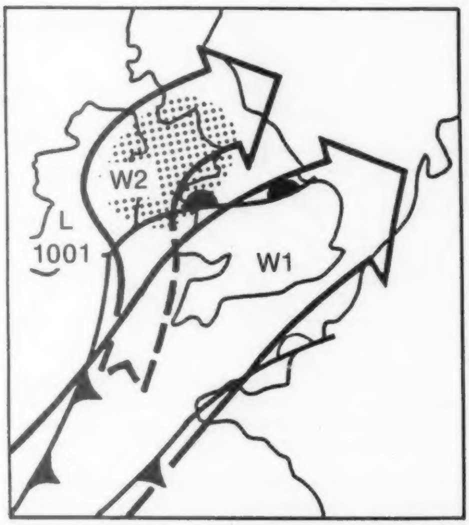

Figure 6. Conceptual model showing major ascending airflows (W1 and W2) and fronts at 09 GMT on 28 July 1988. The model was derived from isentropic analysis of 12 GMT radiosonde data and by inspection of movieloops of images (with conveyor belts displaced to their assumed location at 09 GMT). Stippling denotes the region of heavy rain.

Immediately poleward of W1 lay a tongue of upper-tropospheric dry air which can be seen on the water vapour image for 12 GMT on 28 July (Fig. 8(a)). The cross-section in Fig. 9, was constructed using 12 GMT soundings projected onto line AB on Fig. 8(a). It demonstrates the vertical depth of the dry air (shown as region D in Fig. 7(c)) which partially undercut W1, giving relative humidities below 20% at 500 mb. The dry air over southern England was concealed from view in Fig. 8(a) by the overlying cirrus (UU on Fig. 2(d)). It was this dry air (which isentropic analysis (Fig. 8(b)) showed to have undergone earlier subsidence upstream) that suppressed the depth of the cloud over southern Britain, helping to inhibit the development of precipitation. The role of the dry air will be addressed further in section 4.4.

W1 occupied the region south of the jet axis with wet-bulb potential temperature (WBPT) greater than 16 °C (Fig. 9) and contained cloud areas UU and FF. Almost neutral lapse of WBPT found at mid levels near Brest corresponded to the narrow band of convection over the north coast of France. However, the dynamical processes responsible for the persistent convection are uncertain. The northern frontal zone lay between Aughton and Long Kesh and was most prominent in the lower troposphere as demonstrated by cross-sections of temperature (not shown).

The section portrayed in Fig. 9 bears a striking resemblance to sections through other depressions, one of which is reproduced (from Young 1988) in Fig. 10. Both of these possessed a double structure on satellite imagery, generated by the twin conveyor-belt configuration similar to Fig. 6. Some common features are:

(a) The elevated tongue of warm air aloft corresponding to the WCB of the inner frontal zone. Shallow layers of nearly neutral stability lie along the axis of the warm air (dashed line).

(b) A strong gradient of WBPT exists at middle levels (labelled GU on Figs 9 and 10) along the left-hand side of the WCB. Although the region of tight gradient GU tilts upwards into the cold air, a marked break exists in the strong gradients immediately below. This gap is particularly prominent near

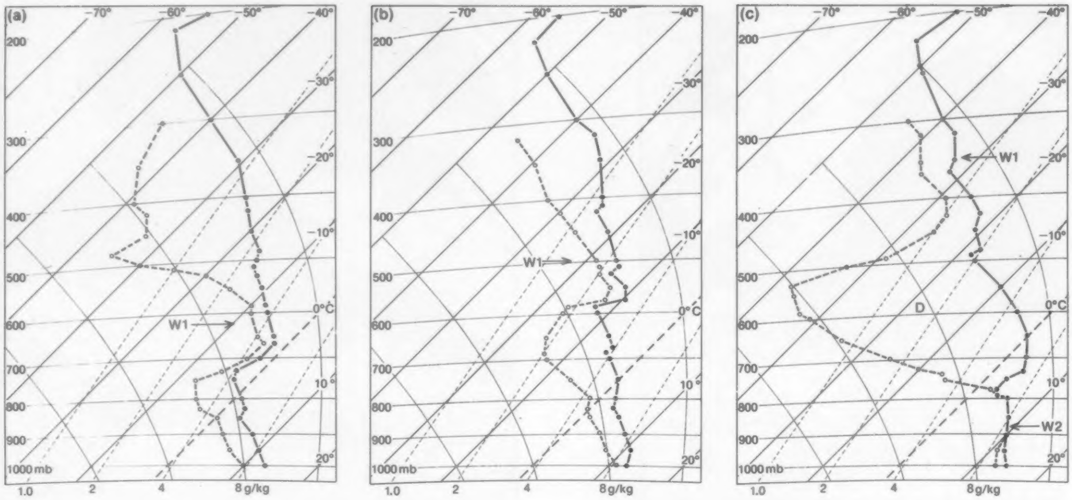

Figure 7. Radiosonde soundings for (a) Camborne and (b) Crawley at 00 GMT on 28 July 1988 and (c) Camborne at 12 GMT on 28 July 1988. The locations of W1 and W2 are shown. The layer of dry air D is referred to in the text.

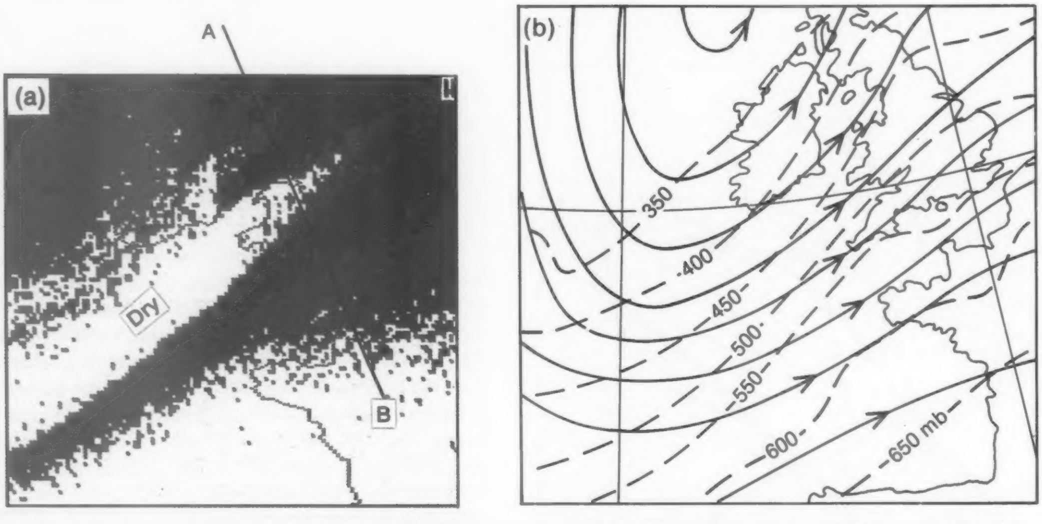

Figure 8. (a) Water vapour image for 12 GMT on 28 July 1988 showing the quantity of water vapour over a depth of the upper troposphere centred around 400 mb. White represents the driest air with successively darker shades representing moister air. AB is the line of the cross-section used in Fig. 9 and (b) isentropic analysis on the 313 K potential temperature surface relative to a system speed of 230° 22 kn. Continuous lines are streamlines and dashed lines are isobars (mb) of the 313 K surface.

750 mb in Fig. 10 and resembles that seen in some of the sections across other cold fronts during the FRONTS87 project (Clough *et al.* 1988).

(c) A marked gradient of WBPT is present in the lower troposphere corresponding to the outer frontal zone, labelled GL in Figs 9 and 10.

4. Fine-mesh model diagnostics

4.1 Performance of the model

This section examines reasons for the poor forecast of rainfall over southern Britain made by the midnight run of the fine-mesh model on 28 July 1988. Fig. 11 shows forecasts of WBPT and rainfall accumulations from runs of the model based on data at 00 GMT and 06 GMT on 28 July. Clearly, the 06 GMT run (Fig. 11(b)) had produced a better forecast of rainfall over England and Wales for 12 GMT (compared with Fig. 1(a)), and the improvement was more pronounced at 18 GMT (Fig. 11(c)). The 06 GMT run had successfully predicted the generally dry conditions over south-east England, and had correctly narrowed the rain band over the south-west, as well as concentrating the heaviest rain over northern Britain. The rainfall totals forecast by the

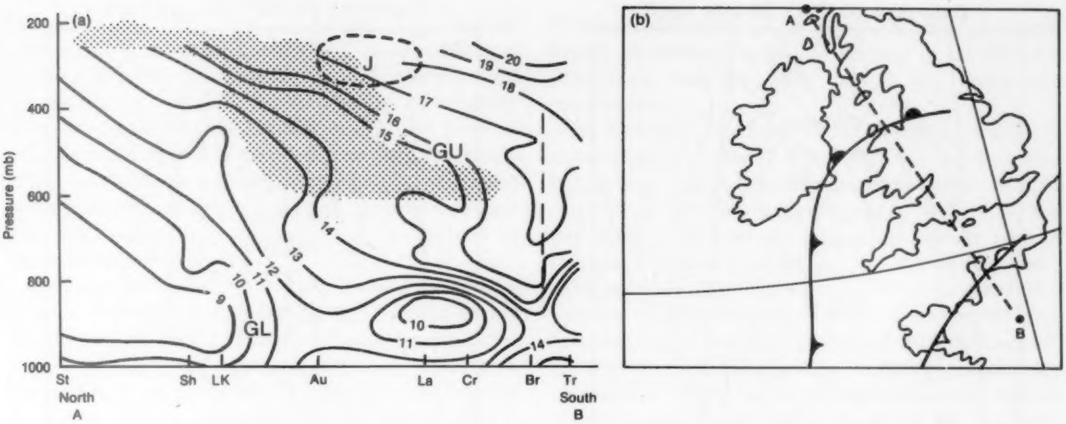

Figure 9. (a) Cross-section of wet-bulb potential temperature (°C) along the line AB in Fig. 8(a) constructed using data for 12 GMT on 28 July 1988. The location of radiosonde stations projected onto the line of the section are as follows: St = Stornoway, Sh = Shanwell, LK = Long Kesh, Au = Aughton, La = Larkhill, Cr = Crawley, Br = Brest and Tr = Trappes. Regions of dry air aloft (relative humidity <50%) are stippled and the jet axis is marked J. GU and GL are regions of strong gradient referred to in the text. The dashed line is the axis of the warm air aloft associated with W1 and (b) line of the cross-section relative to the main surface features.

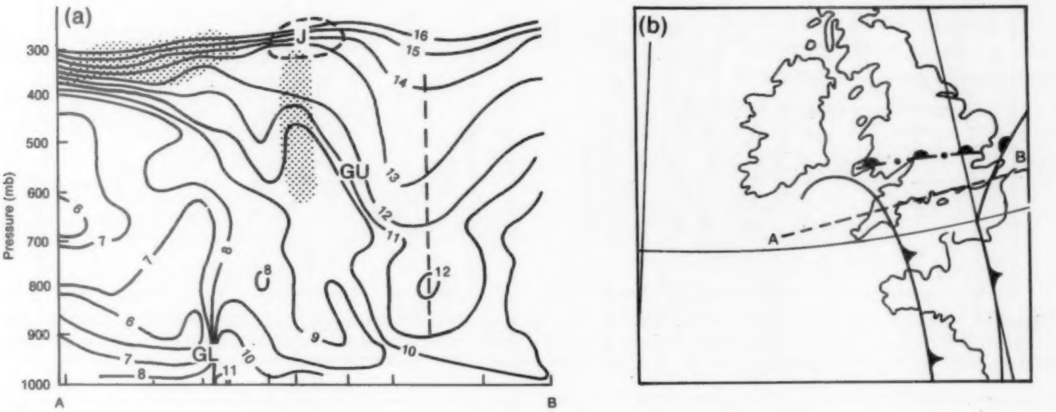

Figure 10. (a) Cross-section of wet-bulb potential temperature (°C) at 0000 GMT on 6 January 1988 and (b) line of cross-section relative to the main surface features. GU, GL, the stippled area and the dashed line are as in Fig. 9. This cross-section benefitted from an enhanced set of radiosonde observations during the FRONTS87 project, the locations of which are shown as short lines intersecting the horizontal axis, and displaced according to the movement of the depression.

mesoscale model (15 km horizontal resolution) based on 00 GMT data (not shown) also exhibited similar errors to the corresponding fine-mesh model. Numerical forecasts based on data from 27 July also produced too much rainfall over southern England despite the humidity analysis appearing essentially correct when compared with satellite imagery.

The elongated tongue of warm air on Fig. 11 characterized by WBPT of 14 °C corresponded to W2. The northern warm front lay at the forward limit of W2 at 850 mb and is depicted in Fig. 11(b). It would be tempting to analyse an occlusion along the entire length of this warm tongue. However, this would be inappropriate because a classical occlusion process did not occur, and secondly, the rainfall distribution (Fig. 5(b)) is not consistent with that implied by a classical occlusion.

4.2 Causes of error in the model's forecast

By comparing the diagnostics from the two runs of the model shown in Fig. 11, it was possible to identify differences in the vertical velocity fields at 12 GMT over the British Isles, which could then be traced back to significant differences in the upper-air pattern at 06 GMT. Differences between the analysis for 06 GMT and the 6-hour forecast valid at this time (run using 00 GMT data) appeared to be related to aircraft reports which were not available for the 00 GMT run of the model. A possible manner in which this data culminated in an improved forecast for southern Britain is described below using diagnostics from both model runs.

The most striking difference between the model fields valid at 06 GMT is in the structure of the jet, shown in Fig. 12. A separate jet streak labelled J, present on the

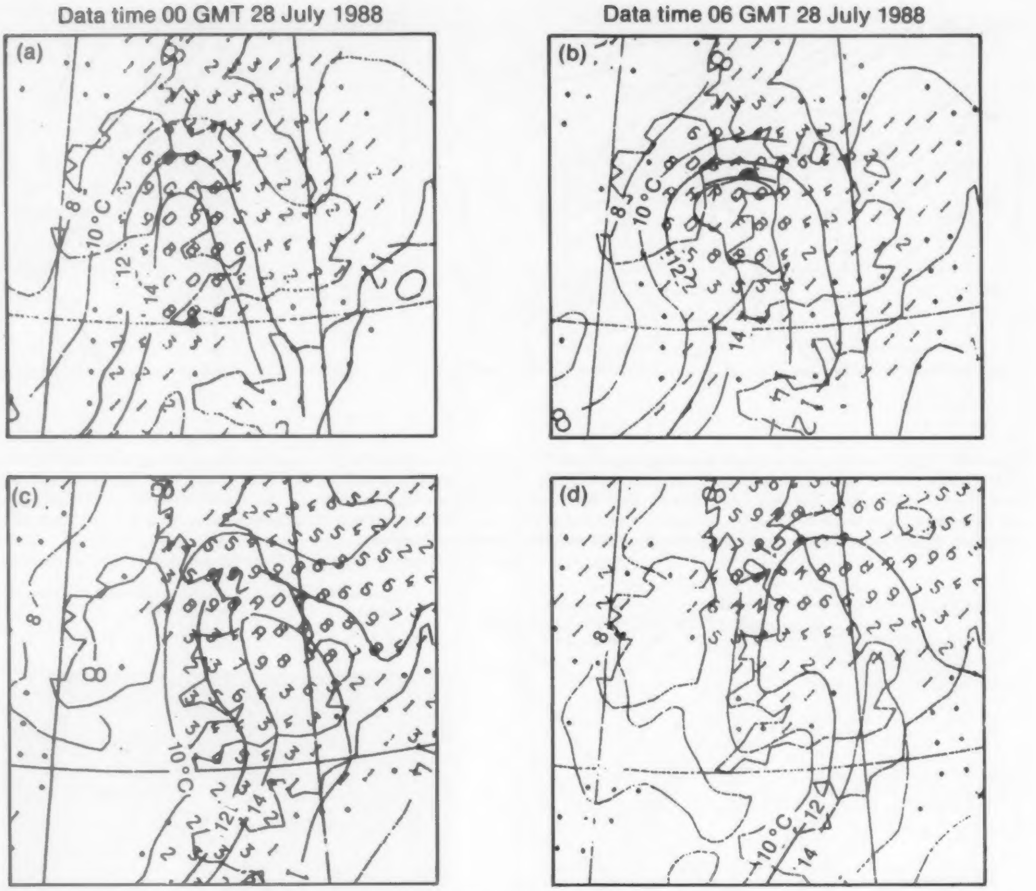

Figure 11. Rainfall accumulations (mm) forecast by the fine-mesh model based on data for 00 GMT on 28 July 1988 (a) and (c) and 06 GMT on 28 July 1988 (b) and (d). (a) and (b) are 6-hour totals up to 12 GMT, whilst (c) and (d) are 6-hour totals up to 18 GMT on 28 July 1988. The letters A, B, C, etc. represent accumulations of 10, 11, 12 mm, etc. Continuous lines are 850 mb wet-bulb potential temperature (°C).

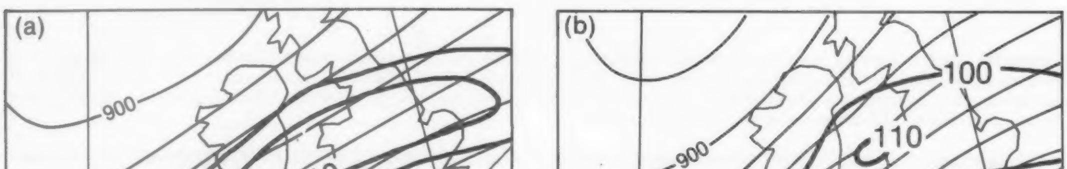

Figure 12. Heights of the 300 mb surface in dam (thin lines) and selected isotachs in kn (bold lines) valid at 06 GMT on 28 July 1988. (a) is a 6-hour forecast and (b) is an analysis. Aircraft observations for 03 GMT are superimposed on (b). J is referred to in the text.

analysis in Fig. 12(b), was not present in the 6-hour forecast in Fig. 12(a) valid at 06 GMT. Its appearance in the 06 GMT analysis was almost certainly due to several aircraft reports at 03 GMT (plotted on Fig. 12(b)) which entered the model via the 03 GMT assimilation. Some of the reported winds were over 20 kn stronger than winds in the same location in the model's 3-hour forecast valid at that time. The jet streak J in Fig. 12(b) may well have existed during 27 July, but could not be resolved by available aircraft reports.

The location of J is shown in Fig. 13 for the same two forecast runs of the model valid at 12 GMT. In the 6-hour forecast (Fig. 13(b)), J had simply propagated eastwards retaining its strength, and much of southern England lay in its pronounced right exit region labelled E. The 12-hour forecast (Fig. 13(a)) had, correctly,

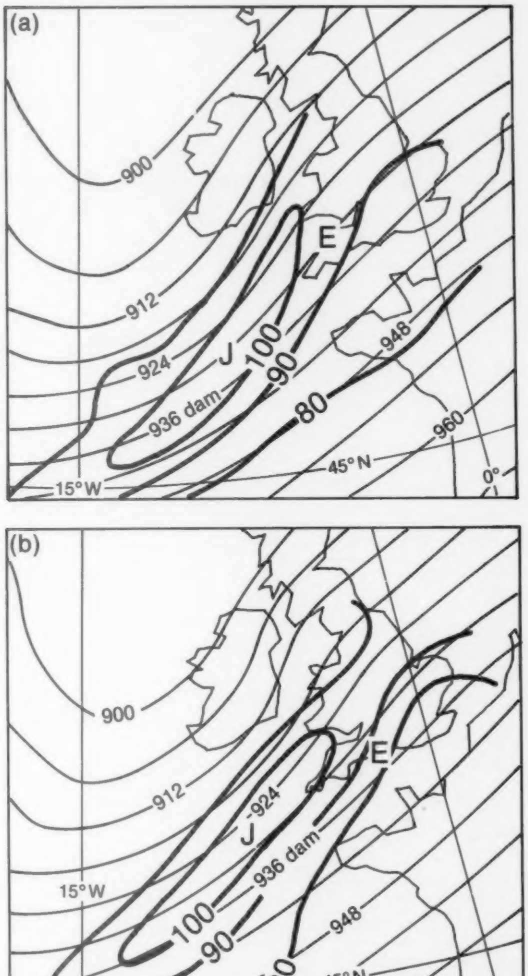

Figure 13. As Fig. 12 except (a) and (b) are 12-hour and 6-hour forecasts respectively. E denotes the right jet exit and other symbols are as in Fig. 12.

developed the same jet in about the right position, despite its absence in the earlier part of the forecast (Fig. 12(a)), but the right exit E was much less pronounced.

At 12 GMT the shape of the elongated region of upward motion on the 12-hour forecast (Fig. 14(a)) over Britain appeared similar to the warm advection field (Fig. 15(a)). By comparing Figs. 14(a) and 14(b), the impact of the jet exit on the vertical velocity field in the 6-hour forecast is marked. With a similar warm advection field (Fig. 15(b)) the upward motion has been doubled in the left-exit region over Wales and the Irish Sea, whereas in the right exit over southern England, the maximum upward motion has been considerably suppressed. These major differences in the vertical velocity fields almost certainly led to the markedly different forecasts of rainfall (Fig. 11) from the two runs of the model.

4.3 Structure of the jet-exit region

Fig. 16 shows vectors of ageostrophic motion valid at 12 GMT on 28 July calculated at 300 mb and 950 mb from both runs of the fine-mesh model. In the 06 GMT run (Fig. 16(b)), at the 300 mb jet exit, there is large component of the flow directed up the geopotential

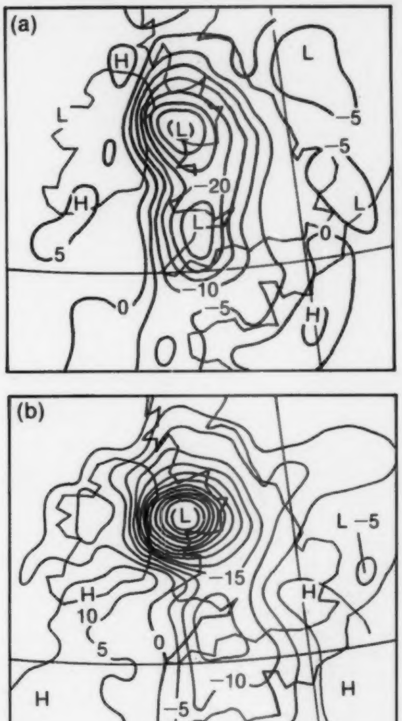

Figure 14. Vertical velocity fields (mb h^{-1}) at 700 mb valid at 12 GMT on 28 July 1988. Negative values represent upward motion and positive values downward motion. (a) and (b) are 12- and 6-hour forecasts respectively. Contours are at intervals of 5 mb h^{-1}.

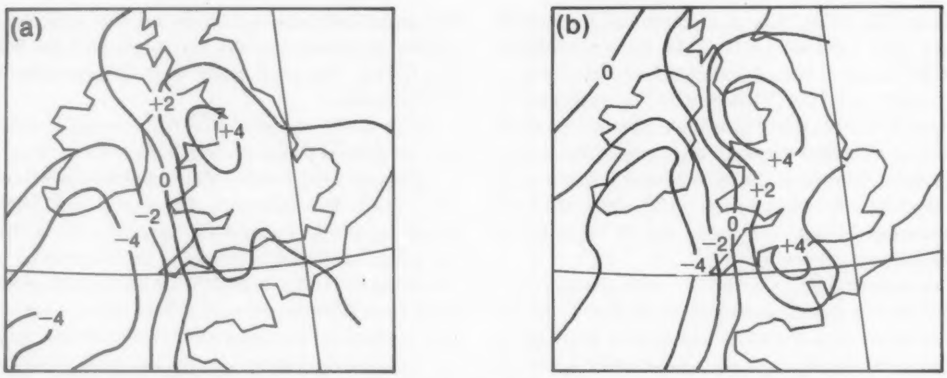

Figure 15. Thermal advection fields (°C $6h^{-1}$) averaged at 850, 700 and 500 mb valid at 12 GMT on 28 July 1988. (a) and (b) are 12- and 6-hour forecasts respectively. Negative values represent cold advection whilst positive values represent warm advection.

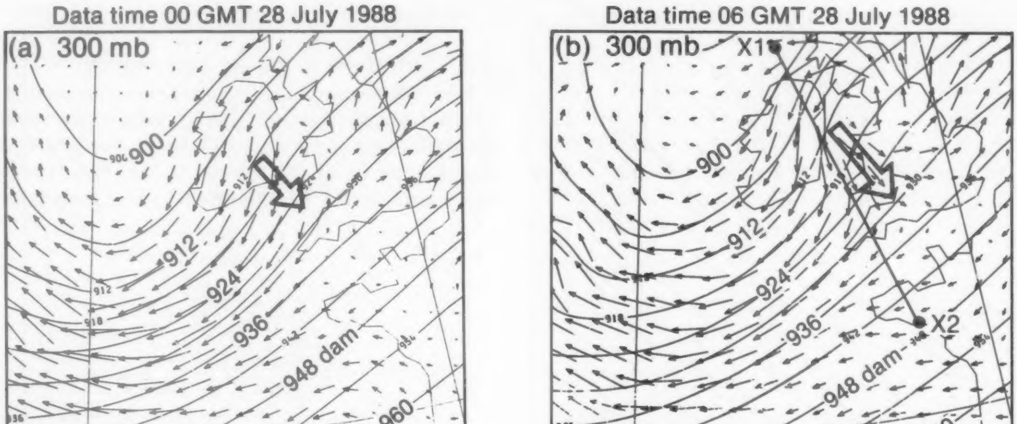

Figure 16. Forecast ageostrophic components of wind (arrows) and heights in dam (continuous lines) valid at 12 GMT on 28 July 1988 based on data for 00 GMT (a) and (c) and 06 GMT (b) and (d). (a) and (b) are for 300 mb whilst (c) and (d) are for 950 mb. The speed of the wind component is proportional to the length of the arrow. Regions in the vicinity of the British Isles with the greatest cross-contour component are indicated with a bold arrow. X1–X2 is the line of the cross-section in Fig. 17.

gradient, whereas directly below, at 950 mb, the reverse is true. This is consistent with the sense of the indirect circulation induced at a jet exit, and W2, along with its low-level jet can be perceived as constituting the lower branch of the circulation. The upper portion of the cross-contour component of the ageostrophic flow is much less marked in Fig. 16(a), consistent with a less well organized jet-exit circulation in the 00 GMT fine-mesh run. The indirect circulation is demonstrated by the fine-mesh model cross-section shown in Fig. 17, taken through the jet exit region. The lower- and upper-level branches of the circulation are coupled by a deep layer of strong ascending motion which corresponds to cloud mass F2. The lower branch transports a shallow layer of air with high wet-bulb potential temperature towards F2. Potential instability (evident, for example, between 850 and 600 mb at point P) is released from the top of this layer giving rise to heavy rain from F2. The tongue of mid-level dry air identified in Figs 8 and 9 is well reproduced in the cross-section. Coupling of upper- and lower-level jet streaks in the manner described could therefore explain the prolonged co-existence of W1 and W2 (from as early as 26 July, Fig. 2(a)), the maintenance of the corresponding double structure to the cloud on satellite imagery and the distinctive rainfall pattern over Britain. A similar coupling process has been described by Uccellini and Kocin (1987) in conjunction with heavy snow events in the eastern USA, and by Browning and Hill (1985) for a polar trough interacting with a polar-front cloud band.

4.4 The role of the dry air

Since the difference between the two forecast runs has been explained without reference to the relative humidity pattern, the role of the dry air identified in Figs. 8 and 9 must be of secondary importance. The dry air originated in a region of marked cold advection upstream (located south of Ireland in Fig. 15) and was advected into the developing system beneath, and to the left of, jet J. Model products suggest that this dry air began to ascend over southern Britain, but not sufficiently far to initiate saturation. The longevity of the mid-level dry tongue, which was essential in maintaining the separate identities of F1 and F2 on the imagery, must imply only weak upward motion in that region (due to suppression of upward motion in the descending branch of the cross-circulation). It was only after the upstream trough began to sharpen significantly after 18 GMT on 28 July that induced ascent on its forward side (due to positive vorticity advection) was sufficiently strong to initiate bands of deep convection that finally penetrated this dry region aloft (Fig. 2(f)).

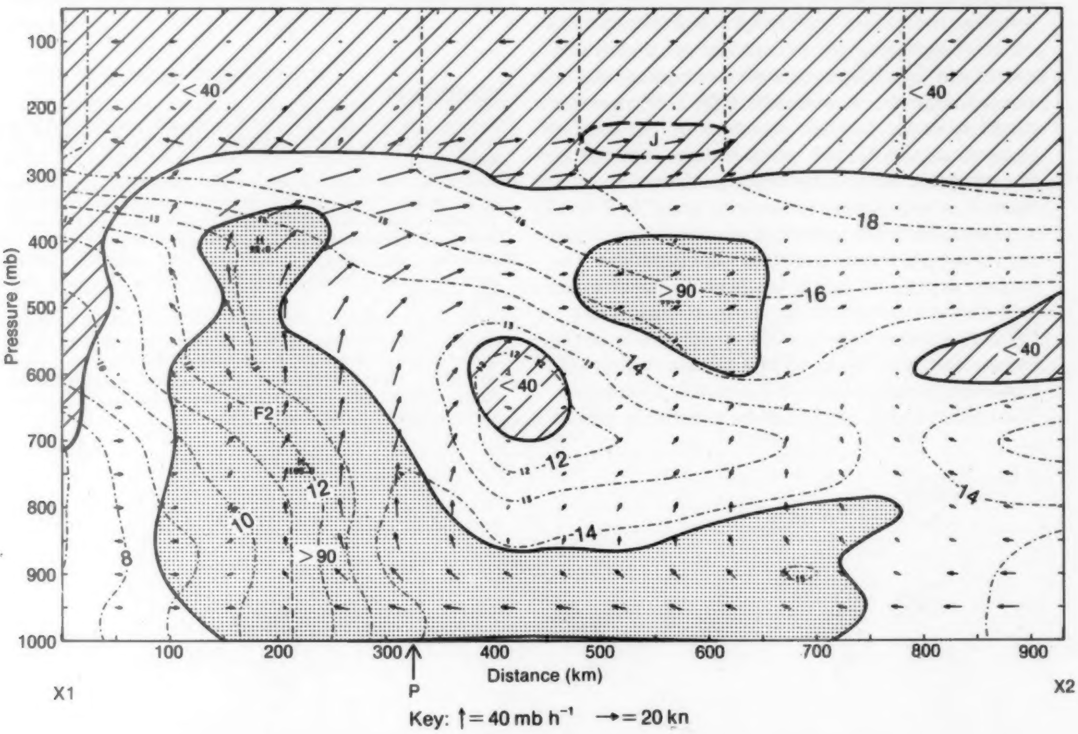

Figure 17. Fine-mesh 6-hour forecast cross-section valid at 12 GMT on 28 July 1988 along the line X1–X2 in Fig. 16(b). Arrows show the components of horizontal ageostrophic motion tangential to the plane of the section, combined with vertical velocity. Isopleths of wet-bulb potential temperature (°C) are shown as dash-dot lines. Regions of relative humidity >90% are stippled and those <40% hatched. J denotes the jet axis which is directed normal to the section. P and F2 are referred to in the text.

5. Forecasting considerations

Key questions of interest to the forecaster in this case would have been:

(a) What was the earliest stage at which the rainfall pattern over Britain could have been predicted?

(b) Would the gap between the two main rain areas persist?

With regard to (a), the existence of the double structure to the cloud signature on 27 July may have suggested a reduction in rainfall intensity between the two frontal zones. However, this hypothesis could not have been confirmed until the system was detected by the radar network. With regard to (b), the initial development of deep convection in the gap, previously occupied by dry air aloft, did not take place until after the northern cloud mass F2 had begun to rotate, by which time substantial cyclogenesis had already occurred. This observation is consistent with the forecasting guidelines presented by McGinnigle *et al.* (1988).

6. Conclusions

The main messages that emerge from this case-study are as follows.

(a) A double cloud band seen on satellite infra-red imagery existed some 36 hours before the associated depression reached the British Isles. The double structure to the cloud pattern led to two distinct areas of rain separated by a corridor of mainly dry conditions (which lay over southern England). Radar rainfall displays, in particular COST-73, provided direct evidence for this structure to the rainfall pattern early on 28 July, which was not captured by the available numerical-model guidance. In such cases it is appropriate to analyse a double frontal structure, this being consistent with the thermal field, the surface observations and the rainfall pattern. The surface depression centre lies beneath warm cloud tops on the south side of the northern cloud mass.

(b) A twin warm conveyor-belt model (similar to the instant occlusion model of McGinnigle *et al.* (1988) explained the observed cloud and rainfall distribution. The configuration appears to have arisen as part of an indirect circulation at the exit of an upper-level jet. The absence of rainfall over southern England was due to suppression of upward motion at the right exit of the jet combined with a deep tongue of dry air aloft. The dry air had originated upstream of the depression through earlier subsidence within a region of marked cold advection. Deep convection occurred within this hitherto cloud-free gap only when cyclonic rotation of the northern cloud mass had commenced.

(c) The coverage of data at 00 GMT on 28 July 1988 was clearly insufficient for the fine-mesh model to achieve the correct upper-air analysis west of the British Isles. As a result, the model's 12-hour rainfall forecast for southern Britain was misleading. Extra aircraft reports at 03 GMT which were available for the 06 GMT model run appeared to be crucial in resolving the strength of the jet and the vertical-velocity pattern necessary to produce a more useful forecast.

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The autumn of 1988 in the United Kingdom

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Meteorological Office, Bracknell

Summary

Autumn temperatures were just below average in most places and while rainfall in northern areas was about normal, central and south-eastern areas had a dry autumn. It was generally sunny except in north-west Scotland where it was rather dull.

1. The autumn as a whole

Although there were mild and cool spells during the autumn, they more or less cancelled one another out to give overall mean temperatures slightly lower than the normal except in northern Scotland and south-east England. Rainfall was generally about average or a little below, but many parts of the south had a relatively dry autumn. November was a dry month everywhere. Sunshine totals were just above average in most places but it was rather dull in north-west Scotland and East Anglia. One or two places in the north Midlands and north-east England were particularly sunny. Information about the temperature, rainfall and sunshine during September–November 1988 is given in Fig. 1 and Table I.

2. The individual months

September. Mean monthly temperatures were generally near normal over the United Kingdom as a whole but somewhat warmer in the east of Highland Region, reaching 0.7 °C above normal at Wick. However, Folkestone, Kent had a mean temperature of 0.8 °C below normal. Sheffield, Weston Park, South Yorkshire reported the highest September maximum temperature, 25.2 °C, since 1982 and the lowest September minimum, 1.9 °C, since 1932. Monthly rainfall totals were below normal nearly everywhere with less than half the normal in many parts of England and Wales. The wettest area was around Cape Wrath, Highland Region with 150% of normal rainfall and the driest places were in southern and eastern areas of England with less than half the normal rainfall with localized exceptions. Sunshine amounts were about normal over the United Kingdom as a whole, although it was somewhat sunnier in the north-east. Amounts ranged from 137% of normal in eastern Scotland to 73% in the Western Isles.

The month started showery in many areas, becoming dry and warm generally on the 5th. Southern areas remained dry on the 6th but there was heavy rain in the north. On the 7th it was sunny in many places and on the 8th and 9th quite warm in south-east England. However, rain in the north and west spread southwards to reach all areas by dawn on the 11th. The showery weather continued on the 13th and 14th followed by a

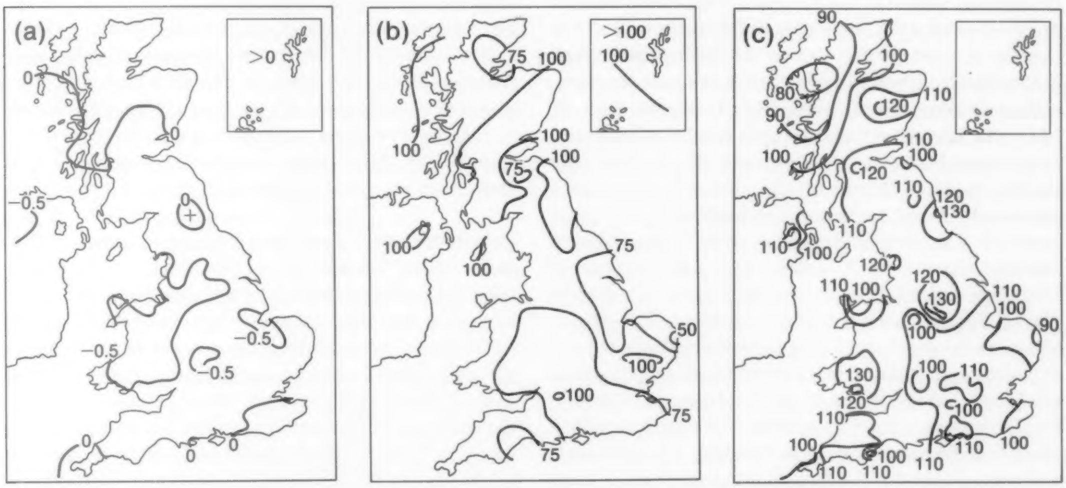

Figure 1. Values of (a) mean temperature difference (°C), (b) rainfall percentage and (c) sunshine percentage for autumn, 1988 (September–November) relative to 1951–80 averages.

Table I. District values for the period September–November 1988, relative to 1951–80 averages

District	Mean temperature (°C)	Rain-days	Rainfall	Sunshine
	Difference from average		Percentage of average	
Northern Scotland	+0.1	0	93	93
Eastern Scotland	−0.1	0	107	111
Eastern and north-east England	−0.3	−2	91	121
East Anglia	−0.4	−2	81	107
Midland counties	−0.5	−3	72	117
South-east and central southern England	−0.1	−3	70	114
Western Scotland	−0.1	0	99	116
North-west England and North Wales	−0.5	−2	84	117
South-west England and South Wales	−0.2	−2	80	118
Northern Ireland	−0.3	−2	99	106
Scotland	−0.1	0	98	107
England and Wales	−0.3	−2	80	116

Highest maximum: 26.7 °C in Midland counties in September.
Lowest minimum: −11.6 °C in western Scotland in November.

period of mainly dry weather with a fair amount of sunshine. After the 22nd most places experienced some periods of wet weather with heavy rain at times. Showers occurred on the 28th, with the first snow of the season falling over the highest parts of the Grampian Mountains. Further showers occurred in the last two days, but most places became dry and sunny.

October. Mean monthly temperatures were below normal generally over Scotland, Northern Ireland and parts of northern England, but about or rather above normal over the rest of England and Wales. In parts of south-east England temperatures were about 1 °C above normal while in the Moray Firth area of Scotland they were almost 1 °C below normal. Day maxima were particularly low in Scotland and north-east England, while night minima were particularly high in the south and east and south-west. The night of the 30th was the coldest in October in Sheffield for 33 years, when temperatures dropped to −1.4 °C. Monthly rainfall totals were above normal in most of the United Kingdom, the wettest places being parts of Tayside and Grampian Regions, with around twice the normal, while Lowestoft, Suffolk had only half the normal rainfall for the month and some central areas of England and Wales were only slightly wetter. However, the thundery conditions produced marked contrasts over small areas and some parts of East Anglia recorded more than 160% of normal. On the 19th heavy rain flooded parts of Liverpool and the Wirral with flood-water 2 m deep in places; Crosby measured 82 mm of rain and Aigburth 42 mm in the day. On the 25th more than 80 mm fell in a day in the area of the Mourne Mountains, including falls of 81 mm at Bryansford and 97 mm at Trassey, Co. Down; many places across the Province had falls of more than 20 mm resulting in flooding, blocked roads and some structural damage. North-east of a line from the Isle of Lewis to the Thames Estuary, October was mainly dull and Orkney and Shetland in particular had 30% less sunshine than normal. Elsewhere, sunshine amounts were normal or slightly above normal, reaching 23% above normal at Cardiff, South Glamorgan. Parts of north-east England were particularly dull from the 15th to the 26th: Leeming, North Yorkshire recorded only 3.8 hours of sunshine during the 12 consecutive days.

Apart from the first few days, a short dry spell at mid month and a dry period at the end, the month was generally wet, with heavy rain at times. The dry spell at the end of the month was interrupted by a few showers near the east coast. Thunder occurred in many parts of England during the 6th and 12th and there was widespread hail on the 6th and 7th. A severe thunderstorm occurred in Northern Ireland on the 12th on the north side of the Mourne Mountains around Bryansford, Co. Down. On the 18th and 19th thunderstorms occurred over a wide area of England and Wales. Aughton, Lancashire reported thunderstorms, severe at times on the 19th. Lightning interrupted power supplies at Stoke-on-Trent. There were showers, sometimes of snow or hail in Scotland on the 28th and 29th. The observer at Keyworth, Nottinghamshire reported that rain-water was cloudy and there was a dust deposit on cars on the 17th. There were further reports of dust deposits in south-east England on the 28th.

November. Mean monthly temperatures were generally above normal in Scotland but below normal elsewhere in the United Kingdom, ranging from 1 °C above normal in the far north-west of Scotland to as much as 2 °C below normal on the south coast of England. Mean monthly rainfall amounts were below normal in most parts of the United Kingdom, the exception being part of north-east England where rainfall was above normal, reaching 124% at Newcastle upon Tyne. Some parts of south-west England and central southern England had less than a quarter of the normal rainfall. It was the driest November since 1956 over Wales, although only

slightly drier than 1983, and over England since 1978. Northern Ireland had the second driest November since 1957. Monthly sunshine amounts were above normal nearly everywhere in the United Kingdom except for some coastal parts of north-west Scotland where it was rather dull with less than 80% of the average. The brightest areas during the month were along the Caledonian Canal, part of central England from Merseyside to The Wash and part of Cumbria and neighbouring Dumfries and Galloway where sunshine amounts were more than 160% of average. The 4th was the sunniest November day recorded at Easthampstead, Berkshire since 1965. Glasgow had its sunniest November since 1947 and at Edinburgh, Botanic Garden it was the sunniest November since records began there in 1939. Wingerworth, Derbyshire reported the sunniest November since records began at the station in 1970.

There were a few outbreaks of cold and wet weather during the month. Early on the 20th, snow over central areas of Scotland moved southwards to affect most of northern and eastern England as far south as east Kent. Snow fell at Oxford where, although snow falling in November is not unusual, the last occurrence of snow lying and covering more than half of the ground in November was in 1969. Wintry showers occurred during the next two days mainly in eastern coastal areas. There were outbreaks of thunder on the 11th in the far north of Scotland, accompanied by hail in places, and on the 20th in east Kent.

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Visit of the Meteorological Office delegation to China, 14–26 May 1989

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Summary

This article concerns a visit made by a delegation of Meteorological Office staff to the China State Meteorological Administration from 14 to 26 May 1989. Both technical and cultural aspects of the visit are described.

1. Introduction

Following an invitation from Mr Zou Jingmeng*, Head of the Chinese State Meteorological Administration (SMA), to Dr John Houghton, Director-General of the Meteorological Office, an Office delegation visited China between 14 and 26 May 1989. The delegation was led by Dr David Axford, Director of Services; the other members were Mr Chris Collier, Assistant Director of the Nowcasting and Satellite Applications Branch and Mr Roger Hunt of the Public Services Branch. Dr Axford and Mr Zou Jingmeng are shown in Fig. 1.

The main purpose of the visit was to learn about the SMA and to discuss with our Chinese colleagues as many of the issues as possible concerning the running of a National Meteorological Service. The visit took place at a time of civil unrest in China but the itinerary went ahead more or less as planned and, in addition to the technical matters, the delegates were still able to enjoy traditional Chinese hospitality and to see something of the country's culture and daily life.

*Mr Zou Jingmeng is President of the World Meteorological Organization.

2. Technical aspects

2.1 Chinese State Meteorological Administration

The SMA is a complex organization, not surprisingly in view of the size of China, with a massive outstation structure for forecasting and climatological purposes. The National Meteorological Centre is at Beijing (see section 2.2) and this includes the Chinese equivalent of the Central Forecasting Office at Bracknell. Underneath that are, or will be, seven Regional Centres — only two are in operation at present — 30 Provincial Bureaux, 300 Prefectural Meteorological Offices and 2400 County Meteorological Stations. Most of these carry out forecasting as well as observing. There are about 600 synoptic stations in China, 200 of which report hourly.

Three major educational institutions come under the SMA, together with a number of secondary technical schools, while at the Headquarters complex in Beijing there is an Academy of Meteorological Sciences and the Meteorological Satellite Centre. The total staff of the SMA is about 65 000.

Figure 1. Dr David Axford (left) and Mr Zou Jingmeng.

One of the interesting facts to emerge was that apart from employing meteorologists and the usual support staff, the SMA is responsible for housing most of its staff, educating their children and looking after their retired staff members. Some of their staff are, therefore, school teachers, doctors, accommodation managers, etc. They even run a rest centre in the south of China at which members of staff can take their holidays.

It also came to light early on that that the SMA has no responsibility whatsoever for aviation forecasting, civil or military. Both of these are run by entirely separate organizations. While conferences take place at an operational level, observations from the civil aviation network are not even passed to the SMA.

Our visit was planned and executed in a highly efficient but relaxed manner by our Chinese hosts to take in the complete range of SMA outstations as well as one of the meteorological institutes and all of the Beijing facilities.

2.1.1 Services at Shanghai Regional Centre

The first stop was Shanghai — the world's largest city and one of the Regional Centres, with 700 staff. Apart from having forecasting responsibilities for a large area of south-east China, there are also climatological and telecommunication sections and a large research section specializing in work on typhoons, storm-surge research and the development of techniques for nowcasting, making use of the good radar and satellite imagery facilities. Severe weather is a problem throughout China, with typhoons posing regular threats to the southern and eastern coastal areas, and severe storms, flash-flooding and hail distributed more widely (Shanghai's record 24-hour rainfall is 515 mm). Forecasts are issued as guidance for their outstations and also for customers, mainly the various local government sections dealing with water, agriculture, etc., but also in a small way to industry and the media.

While in Shanghai we visited a factory making meteorological instruments, and another producing radiosondes, largely for SMA operational use. Both were keen to develop further and to promote themselves internationally.

2.1.2 A Provincial Bureau — Nanjing

We then visited Nanjing in Jiangsu Province; this is one of the Provincial Bureaux and is housed in an attractive 500-year old observatory. The Provincial Bureaux are jointly managed by SMA and local

Figure 2. Old and new in the Nanjing Meteorological Institute — radar dome and satellite receiving dishes amidst traditional Chinese gardens.

government. This potentially confusing situation accounts, for example,for the large numbers of weather radars in the province. There are eight 3 cm radars, three 5 cm radars and one 10 cm radar as well as a 10 cm Doppler radar. This is more than required to cover the area effectively, but the local government divisions are keen to compete with each other. Nanjing has a range of responsibilities, including research work, not dissimilar to the Regional Centre and making use of an impressive array of microcomputers. Since 1985 they have been charging for some services; they currently earn about £85 000 per annum.

We went to the Nanjing Institute of Meteorology (NIM) (Fig. 2), which has about 1800 students including 120 post-graduates. There are basic forecaster courses, although we learned that there is no system for providing regular refresher courses. While at the Institute, Chris Collier presented lectures on 'Recent Advances in Ground Based Weather Observations' and 'Nowcasting in the UK Meteorological Office', both of great relevance to the SMA.

2.1.3 A Prefectural Office — Yang Zhou

One of the Prefectural Offices for which Nanjing has responsibility is in the ancient town of Yang Zhou. During our visit there we appreciated the general difficulties with communications in China. The office was keen to develop services, including commercial ones, and were aware they had a long way to go. However they only received a limited amount of information from their parent offices and some ECMWF and Japanese Meteorological Agency (JMA) forecasts by radio facsimile. For outward communications they had to rely almost entirely on speech using VHF radio.

2.1.4 A County Station — Miyun

While in Beijing, we travelled north to visit Miyun, one of the County Stations at the end of the administrative chain. Here facilities were fairly basic, with forecasters relying on poor copies of Beijing and JMA charts via radio facsimile, and VHF line-of-sight radio for most of their communication. In severe weather in particular (which occurred while we were there), there is radio contact with Beijing for a verbal description of the Beijing radar display.

2.2 Facilities at Beijing

At Beijing, we visited the National Meteorological Centre (Fig. 3), the Academy of Meteorological Sciences (where David Axford lectured on 'The Organization and Structure of the UK Meteorological Office' and 'Weather Services to Civil and Military Aviation in the United Kingdom' and Roger Hunt gave lectures on 'Numerical Weather Prediction in the Meteorological Office' and 'Current Research into Climatic Changes') and the Meteorological Satellite Centre. The latter was well equipped, with 400 staff. The first Chinese meteorological satellite was launched last year, although unfortunately it had an operational life of only about 1 month. At the National Meteorological Centre, forecasters use model output from JMA, ECMWF and the USA. They also run two forecast models of their own, one a 5-layer model of the northern hemisphere with a grid length of about 400 km run once every day at 0000 GMT, and a limited area model with twice the

Figure 3. Dr David Axford seated at a weather radar display with Mr Chris Collier (left) and Mr Roger Hunt (right) at the National Meteorological Centre in Beijing on 20 May 1989. Behind Dr Axford is Mr Li Zechun, Head of the National Meteorological Centre (second from right).

horizontal resolution and the same vertical resolution run daily at 1200 GMT. Forecasts are available about 8½ hours after the analysis time. They are currently developing a 15-level spectral model for use with a Cyber 990 computer which they plan to install in 1990.

3. Cultural aspects and hospitality

3.1. Background

The visit of the British Delegation from the Meteorological Office to China was made at the time of civil unrest with students and the public calling for greater freedom and democracy than they had experienced since the 'New China' was formed in 1949. Student demonstrations and hunger strikes in Tiananmen Square in Beijing began on 13 May and steadily escalated. We arrived in Beijing on Friday 19 May. On the night of Saturday 20 May the Government officially imposed martial law in Beijing, but the Army was held back outside the city by the citizens. On that first night the atmosphere on the streets of Beijing was electric. They were filled with students and citizens who created road blocks at random, and marched up and down with flags. Fortunately they were friendly to English onlookers! During the following week the situation remained tense and unresolved. While initially transport (subway, buses, taxis) stopped, and a general strike appeared to be in force, the situation gradually eased. The hunger strike ceased, but the students stayed in Tiananmen Square. All satellite transmissions from Beijing, including the American television broadcast of Cable News Network (CNN), were stopped from transmitting out of Beijing on 20/21 May, but they seemed to be back intermittently during the week. They were banned again at the end of the week. CNN broadcasts into Beijing were continuously available at our hotel, which had its own receiving dish.

Throughout this difficult period Madam Chen of the SMA continued to carry out the programme of visits as arranged. At times this was difficult. During our visit to Nanjing Institute of Meteorology (NIM) the President, Zhu Qiangen, and his senior staff sat briefing us while the students left the Institute chanting on their way to demonstrate in the city centre (outside our hotel). During the day the NIM lacked students, and Chris Collier's lecture was given to some 30–40 of the Professors and other teachers only. Our programme went close to plan — the only visit not possible was to the Forbidden City — and was arranged on a day-to-day basis as the situation allowed. At times we appeared to know more from the CNN satellite broadcasts in the hotel than did the staff of the SMA. They told us that the Voice of America and the BBC World Broadcasts were jammed at one time. On the weekend after we left Beijing the crisis seemed to have eased, and there was talk of the students giving up.

We returned to the United Kingdom on 1 June. Shortly after (2/3 June) the 27th Army troops were brought into the centre of Beijing to drive out the students. At the time of writing (8 June 1989) there are reports in the media of 7000 dead and 10 000+ injured in Beijing, and the position is totally confused. The UK delegation is saddened and distressed at this news, and most concerned with regard to the safety of the new friends we made during our visit.

3.2. Cultural visits

Our programme was arranged to allow us to make a number of cultural visits, which allowed us to see a wide range of Chinese environments, from the crowds of bicycles and people jam-packed in the narrow streets of Shanghai, and their shanty apartments, to the comfortable spaces in the countryside where farmers can build their own substantial houses for their families. The four classes in China are Party Members, Farmer, Citizens (educated) and Workers — and Farmers seem to do best!

The visits were also arranged to give us background to the New China and its history. In Shanghai we had only two nights, and there was not time to see anything but the mass of people; people crammed into buses, people on bicycles cycling impassively ignoring buses and cars, people walking amongst the cycles, dust and smells which made us cough, live chickens being plucked in a cart, and live ducks and pigs trussed on wagons on their way to slaughter. The culture shock was sudden; we were really abroad for the first time. We visited two factories, travelling through the narrow, winding bustling streets. They were at the bottom end of the range of small companies to be found in the West, located in a few rooms in a street of houses, and unkempt, yet the second factory produces 60 000–70 000 radiosondes a year, and says it could produce 250 000. We visited the Bund, the famous avenue on the banks of the Huangpu River, and the Friendship Shop. Shanghai is a city of 12 million people and is vastly over-crowded.

In Nanjing we found an attractive city with wide tree-lined boulevards and streets. Our hotel, the Jinling, was close to the centre, and the scene of demonstrations by students every day we were there. On arrival at 0830 a.m. in a British Aerospace 146 aircraft belonging to Eastern China Airlines we were first taken to be shown the Chang Jiang Bridge over the Yangtze River. This bridge, 22 000 feet long, was said to be impossible to build, and is shown to demonstrate the abilities of the 'people of the New China.' It was raining, and new young conscripts were being drilled. Our political education continued in Nanjing, notably by visits to the tomb of Dr Sun Yat-sen presented as the father of the New China's philosophy, the 1912 National Charter and Constitution of the Republic. We were then taken to Wu Liang Dau, a Buddhist temple (at which, incidentally, David Axford showed that fortune was on the side of the delegation by placing a coin to stay on a bell and floating another on water) and the Linggu Pagoda which has

nine storeys and, as counted by the delegation, some 257 steps.

During Wednesday afternoon we were taken 'shopping' again, as well as to a Memorial Park (Lighthearted Lake) where we went round a Russian-style exhibit concerning the infamous wife of Mao Tse Tung (Jaing Qing) and her history. That evening, students were massed in the square, and during our walk we could feel the intensity of the crowds. They were all friendly to foreigners, however — no threats, only surprised curiosity.

Our visit to Yang Zhou Prefectural Weather Bureau on Friday 19 May further extended our education. The drivers sped at a crazy speed over the 72 km, and we saw our first views of the open countryside. It is green and cultivated, and pleasant houses (typical 4-bedroomed size in the United Kingdom) were to be seen built by farmers for themselves and their families. In the afternoon a delightful guide took us round the sights at Slender West Lake. The Angling Pavilion, the Wutung Bridge and the White Dagoba all give views which typify the 'China landscapes' we British are brought up to expect.

In Beijing we saw the wide new arterial roads of a modern city again — a lane for vehicles, another lane for bicycles, another for pedestrians. When we arrived the buses, trams and subways had been stopped, so cycles and people were everywhere. Our hotel was 10 km from the centre of Tiananmen Square, but only 100 m from the SMA complex in the west-north-west of the city, which was both convenient and fortunate. It is unlikely that we could have kept to the programme over the critical Saturday to Tuesday period if we had been further away from SMA. Thus despite demonstrations blocking the roads, and one or two nasty moments when our cars were stopped by students who wished to hijack them (I wound down my window to show a Western face, and the driver shouted that he had Englishmen on board), we still drove to and from the SMA on Saturday. On Sunday we headed out of town to the Great Wall of Mutianya, leaving the protests behind us. We took the cable car, and then climbed the steps to the north until at last we found the ancient unrenovated wall, decayed with bushes growing in the central road (Fig. 4). This is an extraordinary scenic visit — it is one of the wonders of the world — and getting there, despite all odds, the British delegation was as one in feeling that we had achieved the high point of the cultural visits. We also noted that the way we took was very steep — some of the steps were like climbing a cliff — and the sun was hot that day.

The Ming Tombs were off the agenda (closed for security purposes), and we did not get out of Beijing again until Tuesday 23 May when we were taken about 72 km north to Miyun County Weather Station. Again we had a chance to see the countryside (Fig. 5). The Forbidden City was closed (!), but on Wednesday the Summer Palace (Yiheyuan) was open. Some students were to be seen relaxing from their vigils in Tiananmen Square and we too were able to relax and take photographs amongst the various Palaces (with titles such as 'Joy and Longevity' or 'Virtue and Harmony') and to take a boat trip to see the 17-arched Bridge and the Temple of the Dragon King.

By Thursday, the situation had relaxed sufficiently for us to visit the British Embassy and (to Madam Chen's pleasure) the Friendship Store, and after confirmation from Zou Jingmeng at the dinner given by

Figure 4. Roger Hunt (left) and Chris Collier standing on the Great Wall of China.

Figure 5. The delegation at Miyun — Dr David Axford (right), Messrs Roger Hunt and Chris Collier (centre and left).

the British delegation on Wednesday evening, we were allowed to stop briefly in Tiananmen Square and take some photos of the student protesters.

Overall, by the time we left on Friday 26 May, we felt that we had seen as good an overview of the eastern plain area of China as was possible in the two weeks available. We were struck most by its 'foreignness'. It is unlike anywhere any of us had been before in Europe, America or indeed the eastern bloc countries (USSR, Hungary, etc.). We had been given a brief education in the history of the New China since 1949. We have seen the people in the midst of a revolution, and they appeared mainly calm and peaceful, friendly and curious when they see an English face. The well-informed citizens we met all seemed to support the students in their desire for more freedom, but there was also a clear message that it may take a long time, and that it was necessary to tread carefully to ensure personal survival. Events since we returned have shown how true this was.

3.3 Official Entertainment

During the visit we stayed in three Western hotels — the Hilton International, Shanghai, the Jinling Hotel, Nanjing and the Olympic Hotel, Beijing. All are first class 4-star hotels which acted as oases of the Western environment and food to which we could retreat after each day in the Chinese city or countryside. We had an American breakfast each day to set us up, and on the few occasions when we were left to our own devices for dinner, we alternated between Chinese experimentation and Western pragmatism.

On arrival at any new Office Bureau or Institute, the procedure was the same. We were ushered into a formal room which contained comfortable easy chairs, and the two 'chiefs' — the Head of the Weather Bureau or Institution concerned and the Leader of the British delegation would sit side-by-side on a settee with a cup of hot china tea on a table in front of them. There would be a few minutes of courteous speeches of welcome and introduction on both sides through the interpreter and an exchange of business cards, then the Head of the Weather Bureau gave a spoken briefing on his Office and its responsibilities. We would then respond with questions and comments, and conclude by offering gifts of varying size, depending on the status of the Office, accompanied by official photographs. We had come prepared with three Meteorological Office shields (the Office crest), a good book of English scenes for Mr Zou Jingmeng and a number of other smaller objects as gifts. They were all accepted gracefully and there were responding small gifts from the higher status Chinese Offices (e.g. a scarf with the local insignia, a Chinese Meteorological Society tie, a small pot from Mr Zou Jingmeng). Then the visit around the location would proceed.

During our 12 full days in China we enjoyed ten Chinese meals, four of which were banquet dinners. We had previously practiced the use of chopsticks and did not resort to western implements at any time. We resisted maotai having sampled it at the first banquet (it is a tasteless liqueur) and thereafter we were served with wine and mineral water. The traditional procedures for formal banquets, including the initial speech and toast by the host and the response of the guest were followed. Fodor's Travel Guide on the Peoples Republic of China, with a section on business travel, proved invaluable here. We ate Cantonese-, Sichuan- and Northern-style food including shark's fin, Peking roast duck, sea cucumbers (slugs), hundred-year-old eggs, braised tendon and fungi of all descriptions. Notable dishes

included squirrel salmon ('squirrel fish with a bushy tail'), steamed turtle fish and bottle gourd duck. We ate out in Yang Zhou at the Vegetarian Fragrance Restaurant in which the dishes look like duck, chicken or sausage but are in fact vegetables. We ate snow mushroom consommé of translucent silver appearance, hot peppery Sichuan bean curd, and duck gizzard. The delegation took it all as it came, and their stomachs survived — protesting mildly.

There were some temporary upsets, lasting at most a day. One was caused by a Western-style meal in which one delegation member was foolish enough to take consommé — clearly the water had not been boiled. Tap water is not potable, or even usable for cleaning teeth, and we used the boiled water in the hotel room or purchased mineral water. The meal at the NIM was notable for its number of dishes. The students were away protesting and the cooks ran amok with over 16 courses. In fact after the President had risen to his feet and we were leaving, two more courses of sweet (sago and coconut) and sour soups covered in fluffy egg white were being brought in. Chris Collier gave his lecture in the afternoon unperturbed. In Beijing we were given another very large Chinese meal at lunch time on Monday 22 May in honour of Roger Hunt's birthday. By this time we knew the scheme of things — sea slugs, antique eggs and fresh frogs legs were tasty morsels and after the customary 12–14 courses a large birthday cake was brought out. Despite a tendency for stupor to set in David Axford and Roger Hunt gave 3 hours of lectures and discussions during the afternoon.

The banquet given by Mr Zou Jingmeng was re-arranged at a nearby location, and the British delegation gave a return dinner in the Olympic Hotel. Both occasions went off well, particularly the latter in which we introduced moatai for the final two courses for Mr Zou, who gave us mandatory 'gambays' (bottoms up) to finish off the visit.

4. Conclusions

Overall, we found there were many areas where the SMA was relatively advanced. The facilities and technology available in some centres were very good and improving quickly. Some of the developments in the fields of Doppler radar, ground-based observing systems, nowcasting and the use of Model Output Statistics were particularly noteworthy. The meteorological research being undertaken throughout the country was clearly of a high standard. It would be correct to say that the research was more academic in nature and less practical in terms of user requirement than is the case in the Meteorological Office.

It was also the case that both the application of the technology in an operational sense and the forecasting services were comparatively undeveloped; there was little attempt to provide customer-orientated products for example. However this has to be seen in the context of an enormous country with big problems in communication systems. It is difficult to provide a complex service using speech via a VHF radio set. For similar reasons, the guidance, data and products provided to the smaller outstations by their parent offices, including Beijing, were lacking in substance. It was hard to see how consistency could be maintained between forecast offices.

Basically it was clear that the SMA has so far put more effort into developing technology and a strong theoretical base than into day-to-day operations and services. In the circumstances this is probably understandable.

We feel that the SMA is developing quickly and will become a major force in world meteorology in the not too distant future. We found the visit extremely useful and enjoyable and is a further step in a growing and hopefully friendly relationship between our two meteorological services.

We are very grateful to our hosts for their great hospitality and for the opportunity of seeing something of the Chinese way of life.

Conference report

The Labrador Sea Extreme Wave EXperiment (LEWEX) Symposium, Applied Physics Laboratory, The Johns Hopkins University, Baltimore, Maryland, USA, 18–20 April 1989

LEWEX was an international effort to assess and compare different methods of measuring and modelling directional ocean-wave energy spectra. From 13–19 March 1987 measurements of directional ocean-wave energy spectra were made using various instruments in the Labrador Sea area. These instruments included drifting buoys, moored buoys, ship- and aircraft-borne radar sensors.

Directional wave-spectra were collected from six numerical wind–wave models driven by four independent wind-field estimates for the same period, and also 'common' wind-fields were used to drive nine wind–wave models; these calculated spectral data were added to the LEWEX data base.

The LEWEX symposium was attended by over 100 people from widely varying backgrounds representing different institutions in Canada, the USA, Australia and six European countries. The Meteorological Office played an important role in the modelling side of the experiment and was represented by Dr P.E. Francis, and Miss K.M. Rider from the wave modelling group in the Forecasting Products Branch. The symposium was the first and probably the last time that all those who had participated in the experiment would meet together to discuss the results and their implications for measuring, modelling, predicting and applying global directional ocean-wave spectra.

Those speaking on measurements discussed the problems of using the instruments during the experiment, and then of interpreting the data and presenting them for comparison with model estimates of directional wave-spectra.

Presentations were given on the performance of each of the wave models from which spectral data had been obtained. Miss Rider described how the Meteorological Office wave model had been used to output spectral data for LEWEX and discussed some of the results.

The symposium was an ideal occasion for everyone attending to broaden their understanding of different aspects of wave measuring and modelling. The general opinion was that there is still a great deal of progress to be made in the next few years, especially in the area of satellite measurements of directional wave-spectra and the assimilation of satellite data into wave models. Hopefully it will be evident that progress has been made towards ensuring success for the next experiment which is being planned for the early 1990s.

K.M. Rider

Notes and news

1990 Watershed Management Symposium, Durango, Colorado, USA, 9–11 July 1990

The Irrigation and Drainage Division of the American Society of Civil Engineers is sponsoring the 1990 Watershed Management Symposium. The purpose of the symposium is to pursue scientific knowledge and to promote sound watershed processes, modelling of wind/water erosion, and application of planning and analysis tools in watershed management.

The symposium will be held on 9–11 July 1990 and will include technical sessions on precipitation and climatic processes, weather modification, infiltration processes, the role of vegetation, wind/water erosion processes, sediment transport/deposition by wind/water, remote sensing, data collection/management, geographic information systems and applications of planning and analysis tools. Session papers will be published in bound proceedings and distributed at the symposium.

Durango is located in the scenic San Juan Mountains of south-western Colorado. Recreational opportunities include hiking, fishing, golf, tennis and river rafting. Major attractions include the Durango and Silverton Narrow-gauge Railroad and Mesa Verde National Park. Durango is served by four airlines, with daily flights from Denver, Phoenix, and Albuquerque.

Requests for placement on the mailing list for future announcements should be sent to:

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Modernization of the US National Weather Service

Recently the National Weather Service (NWS) of the USA (the equivalent of the Meteorological Office in the United Kingdom) has announced modernization plans, to cost $1 billion, for commencement in 1992 and completion by 1995, to equip it for the challenges and demands of the 21st century. The plans cover all the essential components of modern meteorological services — observing systems, communications, computers and forecast offices.

The USA has a population of about four times that of the United Kingdom spread over an area 40 times larger, but with a weather service which will still be only about twice as large in terms of staff and facilities. As a consequence the modernization involves a great dependence on remote automatic sensing systems and communications.Important parts of the new service will be weather satellites, a national network of weather radars and surface weather monitors, all linked to forecast offices by high-capacity communication lines.

The satellite system will use the next generation of Geostationary Orbiting Equatorial Satellites (GOES-NEXT) to replace the present GOES which are situated to the east and west of the USA to monitor the movement of approaching storms. The GOES-NEXT will have capabilities of both cloud imaging and atmospheric sounding. Upgraded NOAA polar-orbiting satellites with increased capabilities for atmospheric sounding in unfavourable cloudy conditions will also be used.

Surface observations of high quality and round-the-clock availability will be provided by 1000 Automatic Surface Observing Systems (ASOS) located mainly at airports. The ASOS observations of pressure, temperature, wind, cloud height and precipitation will be required not only for safe aircraft operations but also to provide warnings of severe storms, often leading to floods. Storms will also be monitored by 121 'Next Generation (Doppler) Weather Radars' to be run by the NWS and supplemented by a further 39 radars operated by other government departments.

The contact with customers will be through a network of 115 forecast offices with sophisticated data processing and display equipment, a reduction from approximately 300 at present using dated technology. There will be a corresponding reduction of personnel, mainly by natural wastage through retirement of World War II forecasters, from about 4700 to 3900. An interesting feature is that many forecast offices will also have hydrologists on their staff.

Finally, to facilitate the movement of data between the forecasters and the observing systems, new high-speed data lines are envisaged, along with new computers, 20 times faster and with 10 times the capacity of the present ones. These computers will be used to produce 2-, 5- and 10-day forecasts and special forecasts when there is a threat of hazardous conditions.

Review

Recent climatic change, edited by S. Gregory. 155 mm × 234 mm, pp. xvi+226, *illus.* London, New York, Belhaven Press, 1988. Price £33.00.

The book contains the proceedings of a symposium (Sheffield 1987) organized by the Study Group on Recent Climatic Change of the International Geographical Union, altogether 27 papers — of different quality as usual. Many papers contribute new data series, mainly on rainfall variability, but also on wind resources and chemical composition of rain-water. Regional aspects prevail, except for the first four papers on global problems.

Bach summarizes model results, but only regarding the expected global mean surface temperature. Using the generally accepted boundaries of warming with doubling CO_2 (1.5 and 4.5 K) and including other trace gases he extrapolates the trend until AD 2100 using three extreme scenarios and (for comparision) estimated palaeoclimatic averages back to the Miocene. Schönwiese compares the effect of different volcanic parameters on past temperature, Jones uses different techniques to obtain truly representative area-averaged data for precipitation. Parker and Folland carefully discuss quality control and corrections to homogenize the historical Sea Surface Temperature (SST) data set of the Meteorological Office; their figures show the enigmatic global cooling between about 1902 and 1912 without comment.

Eight papers deal with Europe and the Mediterranean; which include a comparison of records from the Svalbard area and the role of upper-air patterns, urbanization and cloud seeding on rainfall in Israel. From the six papers on tropical and southern Africa, three deal with relations between the drought-ridden Sahel belt and the SSTs in the tropical oceans. Owen and Folland could simulate significant changes of rainfall and of upper winds as caused by the observed SST, with only minor feedback effects of soil moisture. Using the Goddard Institute for Space Studies model, Druyan found also a strong effect of prescribed SST anomalies, overriding varying initial atmospheric conditions. On the basis of an empirical orthogonal function analysis of SST, Parker and colleagues found some skill in forecasting Sahel rainfall, at least for dry years. In central Sudan, Hulme correlated rainfall with length of rainy season, especially with its termination; a significant role of El Niño Southern Oscillation (ENSO) anomalies could only be confirmed for the Kenya coast (Farmer). Tyson gives some extensions to his recent book (1986). The final nine papers cover other regions, such as the study of rainfall anomalies of north-east Brazil as correlated with Atlantic SST, which indicated also predictive skill. Caviedas outlines the role of ENSO anomalies for South American key regions. Of special value are the collection and evaluation of the wealth of weather diaries at 18 stations in Japan since 1700, with some going back to 1650. Together with an eigenvector orthogonal function analysis of observed rainfall data for 1901–84, a historical record of rainy days during June–July at Yokohama is given for 1710–1895 which shows a distinct but questionable downward trend; significant correlations exist with regions of China and Korea.

The book presents many important empirical aspects of regional climatic change, which substantially supplement and expand our knowledge. There are many instructive illustrations, useful bibliographies and an index containing many names but only few subjects. Due to the variety of items, no comprehensive summary could be given. It is indispensable on the bookshelf of every climatologist interested primarily in facts and applications, while modelling scientists could use it for regional verification (which is only too often underrated).

H. Flohn

Satellite photograph — 5 July 1989 at 0919 GMT

Figure 1. NOAA-10 visible image for 0919 GMT on 5 July 1989.

Photograph by courtesy of University of Dundee

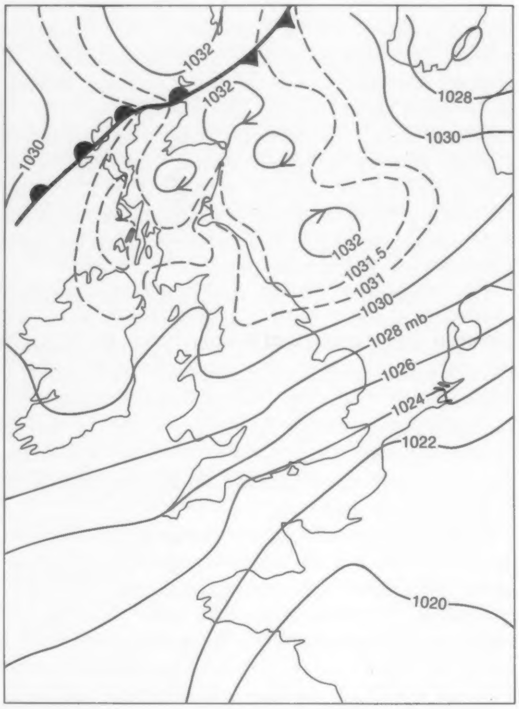

Figure 2. Surface analysis at 0600 GMT on 5 July 1989. Isobars are drawn at 2 mb intervals, but additional isobars are shown near the centre of the anticyclone. (The 0600 GMT analysis is shown rather than 0900 GMT due to there being more observations over the North Sea at the earlier time.)

This NOAA-10 visible image (Fig. 1) was taken during a period of anticyclonic weather when the British Isles was largely cloud free. There were several features of particular interest in the image.

Over the seas surrounding the British Isles, considerable sun glint is present. However, over the North Sea, there is a sharply defined 'black' region, where there is a total absence of glint. Such areas are occasionally seen when the sea is *mirror*-calm such as in the middle of an anticyclone. (If the sea were calm everywhere, then, due to the sun/earth/satellite geometry, glint would be confined to a narrow line roughly parallel to the satellite track.) On 5th July, surface observations in the area (Fig. 2) indicating both calm wind- and sea-conditions suggest this to be the case here. Further, by evening, infra-red satellite data indicated anomalously high sea-surface temperatures in the same area, almost certainly due to the lack of vertical mixing in the calm seas following solar insolation.

The meandering cloud band across the extreme north of Scotland is stratus and stratocumulus marking a weak cold front. The Scottish mainland has acted so as to partially block the southward movement of the front, and to cause dissipation of the cloud.

An upper vortex is present over western France, defined in the image by middle and upper cloud formed during earlier convection. A small but persistent clear area is seen at the vortex centre.

G.A. Monk

GUIDE TO AUTHORS

Content

Articles on all aspects of meteorology are welcomed, particularly those which describe results of research in applied meteorology or the development of practical forecasting techniques.

Preparation and submission of articles

Articles, which must be in English, should be typed, double-spaced with wide margins, on one side only of A4-size paper. Tables, references and figure captions should be typed separately. Spelling should conform to the preferred spelling in the *Concise Oxford Dictionary* (latest edition). Articles prepared on floppy disk (Compucorp or IBM-compatible) can be labour-saving, but only a print-out should be submitted in the first instance.

References should be made using the Harvard system (author/date) and full details should be given at the end of the text. If a document is unpublished, details must be given of the library where it may be seen. Documents which are not available to enquirers must not be referred to, except by 'personal communication'.

Tables should be numbered consecutively using roman numerals and provided with headings.

Mathematical notation should be written with extreme care. Particular care should be taken to differentiate between Greek letters and Roman letters for which they could be mistaken. Double subscripts and superscripts should be avoided, as they are difficult to typeset and read. Notation should be kept as simple as possible. Guidance is given in BS 1991: Part 1: 1976, and *Quantities, Units and Symbols* published by the Royal Society. SI units, or units approved by the World Meteorological Organization, should be used.

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Illustrations

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Sharp monochrome photographs on glossy paper are preferred; colour prints are acceptable but the use of colour is at the Editor's discretion.

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